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ABSTRACT

Piaget's theory of reflective abstraction can supplement cognitive science models of representation by specifying both the act of construction and the component steps through which knowers pass as they acquire knowledge. But, while approaches suggested by cognitive science supplement Piaget by awakening researchers to the role of auxiliary factors in cognition, such as memory space, exemplars, and task environment, they also may leave the incorrect impression that such auxiliaries alone are the essence of cognition. From a constructivist perspective, the concepts of equilibration and reflective abstraction fill a fundamental gap in computational models, for they describe what happens at the moment of understanding. Further, Piaget's concept of "alpha-behavior," which is entirely absent from cognitive science models of cognition, provides a way of comprehending instances in which individuals consciously declare a new competence that is belied by their performance. Including discussions of affective schemas, the role of exemplars, and how and why representational schemas can contain both procedural and declarative aspects, this discussion is developed in reference to two learning contexts: one taken from a study in which students were asked to think like Achilleus in Homer's "The Iliad," and the other from a study of how dancers learn new movement. (RH)

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REFLECTIVE ABSTRACTION AND REPRESENTATION

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Recent work in cognitive science has argued for the centrality of cognitive representation for understanding not only the nature of reasoning, but the nature of mind itself. As Margaret Boden has recently claimed, "The basic reason why artificial intelligence can have something of interest to say about psychological matters is that its central concept is representation, or meaning...the mind is essentially symbolic, or representational." (Boden, 1985, p. 395) The dominant models for such representation have been computational, including the production system, the 'schema,' or domain-specific knowledge structure frequently organized around prototypes, and the temporalization of schematic knowledge in the implicit narratives of 'scenes' and 'scripts' within 'frames.'

This work apparently incorporates much of the Piagetian perspective -- for example, new information being schematized through a dialectic reminiscent of assimilation/accommodation; the person as a theory-builder; the schema itself, like a Piagetian cognitive structure, as both procedural and declarative -- and recent research emanating from Geneva has emphasized procedures and strategies (Inhelder & Piaget, 1980) while Boden, for one, has argued that computational processes are a natural extension of Piaget's work, and that Piaget himself well might have embraced them had they been available when he commenced his research in the 1920s (Boden, 1980).

Yet most cognitive scientists have not associated their work with that

of Piaget, and this for two reasons. First, the tradition of cognitive science emerges out of the confluence of structural linguistics, analytic philosophy, cognitive psychology, and artificial intelligence, not out of developmental psychology or genetic epistemology. Second, and more importantly, the model of the mind that emerges from this work appears at variance with that of Piaget's in fundamental ways. Rather than the earlier Piagetian emphasis on cognitive structures characterized by internally consistent and increasingly adequate logics applicable across domains, cognitive science suggests the structure of knowledge is domain-specific. Though Piaget moved to revise himself on this point (Piaget, 1972), domain-specific knowledge has been shown, in certain cases, to be far more precocious than Piaget would have predicted (Chase & Simon, 1973; Chi & Koeske, 1983). And rather than knowledge being constructed in terms of the logico-mathematical rigor of formal operations, it would appear knowledge may be organized within domains in terms of an informal logic based on heuristics and prototypes (e.g., Rosch & Mervis, 1975; Kahneman, Slovic & Tversky, 1982). Moreover, the empirical work on judgment under uncertainty suggests that not only is the logic of judgments informal, but frequently it is invalid, being subject to a variety of inappropriate strategies such as belief in the law of small numbers, recency effects, and representativeness and availability of exemplars.

Still, while the specific empirical claims of Piagetian theory may need revision in the light of this and other evidence -- and Piaget was his own best revisionist -- the core of Piaget's work is its epistemology, and I would argue that it is precisely on epistemological grounds that cognitive science is most vulnerable. Even though a computational subject replaces the behaviorist's black-box subject in cognitive science models, the epistemological activity of this subject, as opposed to its processing

activity, is still construed to be minimal. Herbert Simon wrote some 15 years ago, "A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself." (Simon, 1969) The identical epistemology seems to inform much of cognitive science.

To take one example, let us look briefly at Roger Schank's recent revision of the script concept (Schank, 1982). Refining his original formulation, he now observes that "Scripts are not a data structure that is available to be found in some part of the storage capacity of memory, rather, script application is a reconstructive process. We build scripts as we need them from our store of knowledge to help us interpret what we hear." Superficially, this sounds unobjectionable; certainly some sort of legitimately constructivist metaphor seems to be at work. But the epistemology that supports this notion -- one that postulates hierarchal levels of event memory, generalized event memory, situational memory, and intentional memory -- isn't. That is, ad hoc positing of hierarchal memory levels may result in an adequate epistemology for representing knowledge in computers. But it severely distorts our conception of how human do it.

Moreover, using this model, Schank goes on to argue that "understanding is finding the closest higher-level structure available to explain an input and creating a new memory node for that input that is in terms of the old node's closely related higher-level structure. Understanding is a process that has its basis in memory." This may sound like Piagetian assimilation. But the subordination of epistemological construction to memory nodes effectively re-conceptualizes Piaget's epistemic subject into a relatively passive agent, possessing well-structured long-term memory, but reactively enriched in its knowing through environmental interaction. As Michael Wertheimer recently argued,

while such models may be perfectly adequate for representing reproductive knowing, they offer no means of understanding how it is that productive knowing, or insight, occurs (1985).

Thus, a surprisingly simple associationist epistemology continues to inform much of cognitive science. The substitution of the rhetoric of "symbols" and "symbol-manipulation" for that of "mental atoms" and "associational links" should not deceive us into thinking that a coherent epistemology has been developed. Simon, for instance, has recently (1979) explained that the connection between a condition and an action in a production system is simply "a special kind of S-R structure." Such an "explanation" is simply a form of cognitive sleight-of-hand, explaining nothing.

So if cognitive science approaches supplement Piaget by awakening us to the role of auxiliary factors in cognition, such as memory space, exemplars, and task environment, they may leave the incorrect impression that these auxiliaries alone are the essence of cognition.

My argument here is that Piaget's theory of equilibration and reflective abstraction fills a fundamental lacunae in computational models, namely the lacunae of describing what happens at the moment of understanding, or of what Piaget called "the grasp of consciousness." In what follows, I will briefly examine a single moment of construction for the epistemic subject -- that which Piaget called "alpha-behavior" -- which I believe is overlooked entirely in cognitive science models. I will look at it in two domains, one properly cognitive, and one where the emphasis is more on action.

Let me begin by situating alpha-behavior with respect to equilibration. Speaking informally, we can describe equilibration as the process by which a knower attempts to understand a given item of

information by situating that item in its overall cognitive system. Such situating is successful as the knower cognitively constructs its understanding of the item through reflective abstraction. However, it is important to note that while equilibration takes place more or less automatically, reflective abstraction does not. A knower may re-equilibrate by denying, implicitly or explicitly, that the new information requires re-thinking. Re-equilibration without reflective abstraction is what Piaget called alpha-behavior. It gives us a means of understanding the common yet counter-intuitive case in which an individual consciously declares a new competence that is belied by their performance. Let me give a concrete example of alpha-behavior, taken from a study in which students were asked to think like Achilleus in Homer's epic, THE ILIAD.

The question posed was whether or not Achilleus, after withdrawing from the fighting against the Trojans as a result of an insult to his honor by Agamemnon, was justified in refusing to return to the fighting after Agamemnon has both apologized and offered significant compensation for the insult. The importance of this question in terms of THE ILIAD as a whole is that unless it can be seen that Achilleus has no legitimate reason not to return to the fighting at this point, the ensuing events of the epic make little sense. Achilleus' anger, at first justified, now becomes an act of <u>hybris,</u> and the punishment he will be made to suffer is the death of Patroklus.

To understand Homer, however, requires that the student has some understanding of Greek thought and values including concepts which have at best a metaphorical equivalence for us, such as <u>arete,</u> <u>logos,</u> or <u>moira.</u> It also includes understanding the nuance in meaning of concepts that are ostensibly identical to ones we commonly use, such as 'honor', which I will

focus on here. a standard of value. To grasp THE ILIAD, then, students must, first, understand Greek values on Greek terms, and, second, apply those values to the text. Clearly, there is a dialectical relation between these two tasks. At the same time, they must refrain from applying their own values, usually Christian or secular American, to the text until after the second step. The importance of this last point should be stressed, for it is precisely this restraint, frequently lacking, that educators may pre-suppose.

Successful reflective abstraction entails two movements. First a cognitive structure must be reflected to a higher level of understanding from which it can be used more generally. I will use the reflective abstraction of coordination to illustrate alpha-behavior. To take a simple instance, Homeric dishonor is an act of fundamental betrayal against self by other, punishable by revenge. That is, revenge is an essential and legitimate component of Homeric revenge. Since many acts of vengeance, both in THE ILIAD and in ordinary life, occur as a result of perceived insults to a sense of honor, such an understanding can serve as a generalized vehicle for comprehension. With respect to THE ILIAD, the signal event with which the epic begins, Achilleus' anger, must be so understood, but such understanding also clarifies the events leading up to the epic -- for example, the golden apple of Eris as revenge for the dishonor of not being invited to Thetis' wedding, the campaign against Troy as revenge for the dishonor of Paris having taken Helen from Menelaus -- and how these conflicts are resolved by the ultimate reconciliation between Achilleus and Priam.

Secondly, though, reflective abstraction also entails mental reorganization, or reconstruction of the relevant parts of the knower's cognitive system, to appropriate this understanding within it. As the

first move promotes generalized application, so the second results in differentiated application, application that is makes sense in terms of the existing understandings of the knower. Thus, to continue the example, cognitively constructing the Homeric sense of dishonor requires locating this concept with respect to the already-possessed value system of the cognizer. This can be tricky, for many students claim they do not believe in revenge. For them, the performance of the second moment will result in an internal, and not necessarily conscious, cognitive conflict, which must be resolved, or re-equilibrated. Successful reflective abstraction results as the cognizer re-constructs its concept of honor to include the Homeric conception as a differentiated moment within it, and is able to see how the Homeric value system is both similar to and different from the cognizer's personal value system. Ideally, the cognizer neither accepts nor rejects the Homeric code uncritically, but situates it with respect to its own code. However, reflective abstraction has not occurred if the Homeric value system is uncritically affiliated to the already existing personal value system, either by seeing the self in terms of Homeric values or, more commonly, evaluating Homeric characters in terms of the values of the self. In these cases, the student is likely to think he "understands" the material when he actually does not. He will show alpha-behavior instead. For instance,

> I would have returned to the fighting. I would have done so because I don't believe that it is right to hold a grudge against someone when they have realized their mistake and offered to make amends for it....Achilleus made his decision based on the information that he had before him. Since he was unaware of God, he couldn't base his decision on the teachings of the Bible.

This example suggests further aspects of constructivism, that of the

movement from egocentrism to decentration, and several of its correlates: (1) the movement of thought from the periphery to the center, (2) the salience of affirmation, and (3) the compensatory but difficult construction of negation. Let me spend a few moments on some of these implications.

First, we see that egocentrism -- the cognitive state of the novice par excellance -- is not an atomic, particulate state of an isolated, Cartesian knower who gradually expands its horizons through associationist links, but rather is an originary global state. Egocentrism includes as unexamined presuppositions the context that supports cognition, a context that is at once affective, social, and cultural. Cognition is not a building up, bit by bit, of components; it is, as Heinz Werner long ago noted, a differentiation and hierarchic reconstruction (or integration) of an originally undifferentiated totality, which includes as essential to it the separation of the knower's perspective not only from that of others, but from its affective and cultural assumptions.

In this context, it can be observed in passing that Piaget's work from the 1940's on the construction of the symbol (translated as PLAY, DREAMS, AND IMITATION IN CHILDHOOD) included a consideration of what he called "affective schemas," structures of organizing experience which because they did not require accommodation through a "purposive generalization" could remain unconscious (1962; cf. pp. 206-210). It should come as no surprise that cognition is frequently captive to affective and cultural biases, and that it will therefore take a correspondingly severe moment of disequilibration to decenter from them. Just as the first permanent object cognitively constructed is likely to be the first affective object as well, namely the primary caretaker, so an awareness of how the affective and cultural interweave with the cognitive help us understand other findings

that seem initially discrepant with a Piagetian analysis.

Thus, prototypes as a basis for natural categorization can perhaps be understood as not defying Piagetian classificatory logic, but corresponding to Piagetian affirmation. The salience of the prototype derives from its common occurrence in the culture coupled with its exemplification of category attributes. The peripheral members of the category are the last constructed precisely because their inclusion relies on the application of formal, definitional criteria. The knower must construct the negation, or compensation, of a non-family resemblance.

Similarly, the failure of adults to show formal reasoning in a variety of contexts and cultures might simply reflect the fact that the highly differentiated reasoning strategies of formal operations are not likely to be displayed when heuristics seem to suffice on an everyday basis (Neimark, 1981). (Whether or not they are sufficient is another question.) There are in fact at least three alternative explanations for this failure, none of which confute Piaget's theory. First, individuals may lack formal competence in those domains where reflective abstraction has not been necessitated, where a global, but imprecise understanding suffices. Thus, reasoning tasks whose formal structure induces performance below competence, such as the Wason-Laird test, show marked improvement when the structure of the test is preserved, but the context is made a familiar one (Mandler, 1983). Second, they may have formal competence but may perform concretely in contexts from which cultural and sub-cultural factors have not been differentiated, as in the example of understanding THE ILIAD cited above. Third, they may be actively encourage to display alpha-behavior by a sub-culture in conscious opposition to the constraints of formal logic (e.g., Lesser & Paisner, 1985), as in common cases of peer pressure, or cultural or ethnic bias. Such an explanation would help account for the

use of heuristics under uncertainty, even and especially when such heuristics lead to inappropriate responses -- i.e, when one follows the reasoning of one's sub-community, and/or relies on the salient features of a situation in an almost pre-operational way.

If Piaget's perspective helps us realize how complex the act of cognitive construction is, it also specifies how and why a representational schema can contain both procedural and declarative aspects. Here we must consider the role of figurative and operative components of knowing in the relation of action to thought. Piaget's counter-intuitive claim concerning the relation between these aspects of knowing is that the figurative is understood and re-constructed in terms of the operative -- that is, in terms of the degree of sophistication that forms of transformation are capable of performing upon the figurative. For Piaget, the development of operativity results from the dialectic between action in the world guided by already existing operative structures, and our re-construction in thought of action in terms of these structures. Cognitive structures result from action, and guide the understanding of action in turn. Consequently, re-construction of structures entails not only accommodation of the figurative (or declarative), but also and more fundamentally, accommodation of operative structures (or the procedural).

The importance of these notions becomes clearer in a domain which emphasizes action, that of movement. A second study we did concerns the question of how dancers learn new movement.

Learning movement can be conceptualized as a two-phase process. First, the dancer must formulate the fundamental movement intended by the choreographer on the levels of body, space, and effort. Second, the dancer must re-construct kinaesthetically what has been consciously imitated, a process that some dancers describe as "getting the movement inside <their>

bodies." We can pinpoint the development of a kinaesthetic sense as the line of demarcation separating novice from expert dancers.

In terms of dance, that which is already known both cognitively and kinaesthetically, functions as cognitive schemas for movement, through which the novel is initially understood. Learning movement, then, consists of incorporating the novel phrase into an existing system of representations, and modifying those representations in turn to 'accommodate' the novel within them. And these 'representations' are not only procedural in the sense of knowing how or when knowledge is to be applied, but exist much more fundamentally as kinaesthetic. How one apperceives movement will depend both on how one understands movement, and what ways of transforming and connecting movement are already embodied as skill.

For instance, novice dancers, with a limited range of movement structures, are engaged equally in increasing their repertoire of movement strategies as in integrating a novel movement. Their learning may be slow and awkward, for they may well realize that they are not yet performing a given movement adequately, yet may lack the structures they need to improve. The movement, at first purely figurative, to be imitated, has yet to be reconstructed operatively, on a bodily level, and not merely on a cognitive one. As it is so learned, it results in skilled perception, that renders salient the particular qualities of the movement which require attention. In other words, to perceive the movement accurately, to represent it figuratively, requires already possessing the necessary operative structures.

A good example is provided by the sequence of stages through which an intermediate dancer describes how she learns movement:

> At first, I used to just mimic what the teacher did and at what counts the phrase was supposed to be. This enabled me to know what the phrase should look like. In other words, I was doing the phrase without committing my body to it, without dancing. This semester, I have tried to get the movement inside me. Granted, knowing the phrase is important but it is really only a small part of dance. I try to feel or sense the movement beginning from the center of my body out to the limbs. Somehow I have been able to define words like 'elasticity' to a certain body movement. I don't know how I did it, I just felt it one day and I have tried to remember that feeling ever since. And I also find that the bigger I make the movement, the easier it is to get the phrase and to find that feeling of my whole body working together as a whole.

More advanced or experienced dancers, possessing a larger repertoire of strategies to draw upon, can usually incorporate novel movement both more efficiently and more expeditiously.

Conversely, merely possessing prior cognitive structures is no guarantee that learning will be successful, for an unwillingness or an inability to reconstruct structures can lead dancers to believe they have understood or mastered a movement when they in fact have not. The clearest example of this kind of phenomenon is that of the "bad habit," in which a movement is so well integrated kinaesthetically that it resists change, even though it is inefficient or incorrect. This is alpha-behavior on the level of movement. In these not uncommon cases, learning must include breaking down the inefficient movement structure at the same time as a more efficient one is achieved.

For instance, in the following two descriptions of learning movement by experienced dancers, the inability to completely integrate the cognitive level with the movement level prevents them from becoming "expert" dancers.

> When I learn movement there are three steps that I go through. First, I watch the whole movement to get an overall view of the intent. Secondly, I try to associate it with a movement that my body already knows. Finally, I rely on counts to learn new movement. I learn where in space my body should be at a given time and how long I can move my body through a predetermined path.

> I learn movement cognitively as opposed to intuitively. Through intentional observation, I categorize movement into chunks of already learned concepts. The way I learn is rigid in that the combinations are not transferable to "the other side" or "to the back." In order to perform in other directions, learning has to take place all over again.

Especially in the second case, we can see that the student possesses movement structures, but so inflexibly that they pre-determine the form of the movement, rather than accommodating to it.

The kinaesthetic process here is isomorphic to the cognitive process, described earlier, of coordinating value codes. In both cases, what one already does or knows must be differentiated from, and reconstructed in relation to, the novel, and the total system re-equilibrated through being re-integrated. Well-structured knowledge representations may well prove

inadequate to learning if the act of construction by the knower is not also addressed.

It is with the focus on the constructivism of the knower that I wish to conclude. An important motif in discussions of cognition has been the role of the exemplar. It appears, among other places, in Rosch's work on natural categorization, in the representation systems of novices and experts, and as a means of providing tutorial examples that hone rule induction of expert systems (Michie, 1985). Exemplars are paradigm cases for cognitive science, for they incorporate both declarative and procedural components, providing both a particular example of a domain, and a system of rules through which the example can be operated upon.

Yet the way in which exemplars function in the representational systems of experts is misleading if we wish to understand the construction of knowledge. While expert representation may be the most efficient, or highly organized, or powerful, it need not embody the form of how the representation was constructed. To give one example, Karmiloff-Smith (1982), in an investigation of children's representations of a railroad track layout, found that first representations of the layout were topologically accurate, but there ensued an intermediate, highly distorted phase which incorporated overdetermined figurations of curved track. Finally, the representations reached a final, stable form. The distorted, intermediate phase followed the children's physical manipulation of the tracks in the layout, during which the curvature of curved track was apparently emphasized. The final representation of the track passed through and reconstructed the intermediate phase, which itself was the reconstruction in action of a first, purely figurative phase. In this instance, to have only offered the final, expert representation would have given no clue of the stages of construction and reconstruction that led to

it. A similar example is provided by students' construction of the concepts of mathematical induction and compactness, reported by Dubinsky and Lewin (1986). In other words, expert representations are genealogically inaccurate. They may tell us the most efficient form in which knowledge can be represented, but they tell us little of the history of how that form was constructed.

To conclude, then, I would argue that Piaget's theory of reflective abstraction can supplement cognitive science models of representation by specifying both the act of construction and the component steps -- in all their hesitation and "wrong turns" -- through which knowers pass as they acquire knowledge. If we wish to understand the psychology of cognition, and not only its finished, computer-simulatable form, such an account of its genesis is essential.

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